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Linking Investments in Telecoms and Economic Growth: An Empirical Analysis of Total Factor Productivity and its Determinants in the Context of Transition Economies

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ABSTRACT

The limited resources of Transition Economies (TE) accentuate the need for formulation of the effective and efficient policies for investments in Information and Communication Technologies (ICT). However, the empirical evidence required for sound decision making is scarce, thus prompting a call for additional studies in the area of the macroeconomic impact of investments in ICT. Using time series data for the period from 1993 to 2002, we investigate the impact of investments in Telecoms on Total Factor Productivity (TFP) in the context of 18 TEs of Central Europe. The results of the data analysis suggest that while all TEs exhibited overall growth in productivity, the annual growth of the majority was inconsistent and not determined by the increase in the levels of investments and full-time Telecom labor. The results also indicate that introduced for the purposes of the investigation composite proxy variable Change in Productivity may reliably serve as a predictor of TFP for eight out of eighteen TEs, thus indicating actionable paths for TEs to obtain a spillover effect from investments in ICT.

Keywords

Investments in ICT, Economic Development, Total Factor Productivity, Transition Economies

INTRODUCTION

An overall reduction in the level of investments in Information and Communication Technologies (ICT) is just one of the likely results brought about by the current economic conditions. The depth of the reduction, however, is not going to be uniform across all economies. During the 1990's, the impact of investments in ICT on the macroeconomic bottom line was especially pronounced in the United States (Oliner & Sichel, 2000; Van Ark *et al*., 2002; Jorgenson, 2003) and, albeit to a lesser degree, in some of the OECD countries (Colecchia & Schreyer, 2002; Van Ark *et al*., 2002). Because it has been established that investments in ICT contribute reliably to the macroeconomic bottom line of the developed countries (OECD, 2002), the reduction in the level of investments in these economies might be minimal.

In the context of developing and Transition Economies (TE), however, the outcomes of investments in ICT are mixed (Dewan & Kraemer, 2000) and the research is scarce; as a result a TE might be required to present evidence that such investments can be effectively and efficiently transformed into macroeconomic output. Moreover, despite the significant increase in the level of adoption of ICT by European countries in the period around 1998-2002, their levels of productivity, unlike those in the US, started to decline and disparities in the macroeconomic outcomes of investments in ICT among the different economies became obvious (Daveri, 2002). Such reduction in growth, even among well-heeled developed countries, clearly requires TEs to demonstrate that their limited technical, financial and human resources are not wasted (Indjikian & Siegel, 2005).

From the perspective of the widely used framework of neoclassical growth accounting (Brynjolfsson & Hitt, 1996), an increase in the macroeconomic bottom line, often represented by GDP, can come from two sources. The first source is provided by the available levels of capital and labor, and the second source is reflected by Total Factor Productivity (TFP). While the most straight forward way of improving a macroeconomic bottom line is simply by increasing the levels of available capital and labor, with limited resources a contribution coming from TFP is preferable, for it represents the macroeconomic growth that is not accounted for by the increase in the levels of capital and labor, and is not a subject to the law of diminishing returns. Most investigations linking ICT and growth in productivity have been conducted in the context of developed countries (McGuckin *et al*. 1998).

The overall purpose of this inquiry, conducted in the context of TEs of Europe and the former Soviet Union, is to identify whether the ICT sector of these economies exhibited growth in TFP (heretofore we use TFP and *productivity* interchangeably) associated with investments in ICT; specifically, we investigate two periods: a period of early transition (1993-2002) and a period of a later transition (2003-2008). We have decided to begin our analysis from year 1993 because it provided a common starting point for TEs. Our reasoning was that it took a year from the fall of the Berlin' Wall in 1991 for the process of transition to start, and year 1992 as a starting point could have favoured "early starters." After that, ten years appeared to be a reasonable period of time to allow for the changes to occur and the first results to take place. The duration of the second period was primarily determined by the availability of the relevant data.

While limiting this study to investments in Telecoms, regarding Telecoms as a surrogate for general ICT, we aim to answer two major questions: 1) *do the TEs in the sample exhibit continuous growth in TFP*, and 2) *what are some of the factors impacting growth in TFP*? The potential for investments in ICT to generate high levels of productivity growth in the context of TEs has been noted (Indjikian & Siegel, 2005); however, it is not clear whether that potential has been realized. Previous investigations established that in order for investments in ICT to impact the economic bottom line, the level of investments must be above a certain threshold, and also such investments must be complemented by other factors, notably, investments in human resources (Bresnahan *et al*., 2002; Brynjolfsson *et al.,* 2000; OECD, 2004). In this study we focus on the following detailed questions that flow from our major research questions:

1. RQ1: Does the given TE exhibit Annual Growth in TFP?
2. RQ2: Does the given TE exhibit Continuous Growth in TFP?
3. RQ3: Is there a Relationship between changes in the Level of Investments in Telecoms and changes in TFP?
4. RQ4: Is there a relationship between changes in the Level of Full-time Telecom Staff and changes in TFP?
5. RQ5: Do changes in the Level of Investments in Telecoms & changes in the Level of Full-time Telecom Staff produce a complementary effect on changes in TFP?
6. RQ6: Is there relationship between the Level of Investments in Telecoms and TFP?
7. RQ7: Is there a relationship existed between the Level of Full-time Telecom Staff and TFP?
8. RQ8: Are the level of Investments in Telecoms & the Level of Full-time Telecom Staff complementary in terms of their effect on TFP?
9. RQ9: Do changes in the Ratio of Revenues to Investments impact TFP?
10. RQ10: Does the Level of the Ratio of Revenues to Investments have an impact on TFP?
11. RQ11: What is the dominant source of growth in TFP?

The importance of these research questions is intuitive, for answers will allow not only for a prudent allocation of limited resources (e.g. human and investment capital), but also offer some insights regarding the more effective and efficient conversion of investments into the macroeconomic bottom line. To answer the research questions, we employ Data Envelopment Analysis (DEA), Multivariate regression (MR), and Ordinary Least Squares Regression (OLS) as our main data analytic tools. DEA is a widely used method for evaluating productivity and performance and is commonly combined with other techniques, such as cluster analysis (e.g. Shin & Sohn, 2004, Hirshberg & Lye, 2001; Lemos *et al.* 2005), neural networks (e.g. Samoilenko & Osei-Bryson, 2008a; Celebi & Bayraktar, 2008), decision trees (e.g. Samoilenko & Osei-Bryson, 2007; Wu, 2009), and regression analysis (e.g. Cooper & Tone, 1997). We explore our research questions within the context of two time periods, 1993-2002 and 2003-2008. This permits us to assess whether there any significant differences between these time periods.

DESCRIPTION OF THE DATA

The data for this study were obtained from the *World Development Indicators* database, which is the *World Bank*'s (web.worldbank.org) comprehensive database on development data, and the *Yearbook of Statistics,* which is published yearly by *International Telecommunication Union) (*www.itu.int*).* The designation of TEs is applied to the countries that are in the process of transitioning from a centrally planned economy to a market-oriented economy. To minimize the heterogeneity of our sample we identified TEs that started the transition at about the same time. Looking at the twenty-five countries classified as *Transition economies in Europe and the former Soviet Union* by IMF (2000) we selected the following 17 transition economies (data on the rest was incomplete, and therefore not useable for our study): Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Moldova, Poland, Romania, Slovakia, Slovenia, and Ukraine.

For the selected TEs we were able to construct two data sets, a data set covering the period of earlier transition from 1993 to 2002, and a data set spanning the period of later transition, from 2003 to 2008. However, the TEs are not homogeneous, in

terms of their development. It has been noted that TEs tend to share economic characteristics with both developed and less developed economic regions (OECD, 2004).

RESEARCH METHODOLOGY

In order to answer eleven research questions of this study we employ a four-phase methodology supported by three data analytic tools; a summary is provided in Table 1.

Phase #	Research question	Tool
Phase 1	RQ1: Does the given TE exhibit Annual Growth in TFP? RQ2: Does the given TE exhibit Continuous Growth in TFP?	DEA, MI
Phase 2	RQ3: Is there a Relationship between changes in the Level of Investments in Telecoms and changes in TFP? RQ4: Is there a relationship between changes in the Level of Full-time Telecom Staff and changes in TFP? RQ5: Do changes in the Level of Investments in Telecoms & changes in the Level of Full-time Telecom Staff produce a complementary effect on changes in TFP? RQ6: Is there relationship between the Level of Investments in Telecoms and TFP? RQ7: Is there a relationship existed between the Level of Full-time Telecom Staff and TFP? RQ8: Are the level of Investments in Telecoms & the Level of Full-time Telecom Staff complementary in terms of their effect on TFP?	MR
Phase 3	RQ9: Do changes in the Ratio of Revenues to Investments impact TFP? RQ10: Does the Level of the Ratio of Revenues to Investments have an impact on TFP?	OLS
Phase 4	RQ11: What is the dominant source of changes in TFP?	DEA, MI

Table 1 A Four-Phase Methodology of the Study

We provide a detailed outline of each of the phases next.

Phase 1

To approach our research problem we rely on the neoclassical framework of growth accounting, originated from the work of Solow (1957). The objective of growth accounting is to decompose, using a neoclassical production function, the rate of growth of an economy into the contributions from the different inputs. A neoclassical production function relates output and inputs in the following manner

$$\mathbf{Y} = f(\mathbf{A}, \mathbf{K}, \mathbf{L}),$$

where **Y** = output (most often in the form of GDP), **A** = the level of technology/total factor productivity (TFP), **K** = capital stock (or, investments in Telecoms in the case of our study), and **L** = quantity of labor/size of labor force(or, quantity of full-time Telecom employees in the case of our study).

Out of three inputs used by growth accounting, only capital ***K*** and labor ***L*** could be observed in the data, while TFP serves as a residual (often referred to as *Solow's residual*) term capturing that contribution to ***Y*** (GDP or revenues from Telecoms), which is left unexplained by the changes in the levels of capital ***K*** and labor ***L***. The value of TFP could be obtained by calculating the value of Malmquist Index (MI) of TFP growth (Malmquist, 1953: Caves, Christensen& Diewert, 1982), which can be constructed based on the results of Data Envelopment Analysis (DEA) (Färe et al.,1994). Essentially, the approach is based on performing DEA analysis in two points in time; let us say t1 and t2. Then, for a given DMU, the period of time (t2-t1) can be represented as the distance between the data point at the time t1 and the data point at the time t2. For each DMU in the sample, the distance between these data points is reflective of the change in this DMU's TFP, which is represented by the Malmquist index. If the obtained value of MI is greater than 1, then the change is positive, conversely, if MI is less than 1, the change is negative. In the case of economic growth, we expect that the efficiency frontier for a given set of DMUs would change its position favorably over time, which will be indicated by the values of MI>1.

In the case of our investigation we have 10-year time-series data (from 1993 to 2002), and a 6-year time-series data (from 2003 to 2008); consequently, we can obtain, correspondingly, nine and six values of MI, where each value serves as a measure of TFP for a given year. For the DEA part of the methodology, we have identified a model consisting of the six input and four output variables, presented below.

The main goal that we pursue in performing DEA is to find out how efficient our set of the transition economies are in converting investment inputs into revenue outputs. Therefore, we did not include any other types of inputs or outputs such as those related to infrastructure, capabilities, utilization, etc. It is should be mentioned that the purpose of our DEA model is not to reflect the path by which the investments are transformed into the revenues over the course of one year, rather, the intent of our model is to depict a 'fiscal efficiency' of the TEs regarding their investments in Telecoms.

Input variables of the DEA mode	**Output variables of the DEA model**
GDP per capita (in current US $)	Total telecom services revenue per telecom worker (in current US $)
Full-time telecommunication staff (% of total labor force)	Total telecom services revenue (% of GDP in current US $)
Annual telecom investment per telecom worker (in current US $)	Total telecom services revenue per worker (in current US $)
Annual telecom investment (% of GDP in current US $)	Total telecom services revenue per capita (in current US $)
Annual telecom investment per capita (in current US $)	
Annual telecom investment per worker (in current US $)	

Table 2 DEA Model, Input and Output Variables

We present the levels of investments and revenues not in absolute dollar terms, but in relative units. The intent in doing so was to counter the differences between TEs in terms of their size, population, level of wealth, while representing the investments and revenues more broadly (i.e., relative to the whole population, labor force of a country and the telecom industry).

Phase 2

The second phase of our inquiry is dedicated to determining the presence of statistically significant relationships between the values of TFP, investments in Telecoms, and a full-time Telecom workforce. While Samoilenko and Osei-Bryson (2008b) presented evidence of the relationships between investments in ICT and full-time ICT labor and GDP in the context of TEs, it has not been shown that such a link exists in regard to TFP. Furthermore, we aim to determine whether these two variables (investments and labor) are complementary in their effect on TFP. The second and third phases of our investigation employ regression analysis.

In this investigation we are interested in the presence of a statistically significant effect of the independent variables on the dependent variable. In this case, the general model of MR takes the form:

$$Y = a + b_1{*}X_1 + b_2{*}X_2 + b_3{*}X_1 X_2 + e$$

and the test for presence of a statistically significant effect amounts to testing the null hypothesis

$$\boldsymbol{H_0}: b_1, b_2, b_3 = 0$$

In the case of $b_1, b_2, b_3 \neq 0$ we are able to reject the null hypothesis of the study. However, because TFP represents change (annual, in the case of this study) in productivity, we can also express the variable *annual telecom investment (in current US $)* in the form of the change in the level of investment that took place over the year; similarly, we can express the variable *full-time telecommunication staff* in the form of the change in the level of full-time Telecom labor that took place over the same year. As a result, in the first MR model we use variables listed in Table 3.

Term in the first MR model	**Variable**
Y1	TFP
X1	Annual change in the level of telecom investment (in current US $)
X2	Annual change in the level of Full-time telecommunication staff
X1*X2	Interaction Term

Table 3 Variables in the first MR model

Consequently, the first MR model takes the following form:

*TFP = a + b_1*annual change in investments in Telecoms + b_2*annual change in full-time Telecoms staff+ b_3* annual change in investments in Telecoms*annual change in full-time Telecoms staff + e*

Moreover, we also aim to determine whether the values of TFP are affected by the *levels* of the variable *annual telecom investment (in current US $)* and the variable *full-time telecommunication staff.* In the second MR model we use variables listed in Table 4.

Term in the second MR model	Variable
Y1	TFP
X3	Annual telecom investment (in current US $)
X4	Full-time telecommunication staff
X3*X4	Interaction Term

Table 4 Variables in the second MR model

As a result, the second MR model takes the following form:

TFP = a + b_4 annual telecom investment + b_5* full-time telecommunication staff + b_6* annual telecom investment * full-time telecommunication staff + e*

Phase 3

There appears to be an agreement of the importance of the effectiveness and efficiency of the workforce on productivity (Samoilenko & Osei-Bryson, 2008a). It is not clear, however, whether there is a relationship between the capacity of the workforce to convert investments into revenues and TFP in the context of TEs. In order to investigate this issue further, we employ a proxy variable *conversion efficiency,* which is represented by the ratio of the variable *total telecom services revenue in current US $)* to the variable *annual telecom investment (in current US $),* per full-time Telecom worker. The use of generalized indexes (e.g., *e-readiness, Network readiness, IT diffusion*) and proxy variables (e.g., *IT intensity*, *Access, Connectivity*) is common in studies of economic impact of IT (Indjikian and Siegel, 2005). The proxy variable *conversion efficiency* serves as a good intuitive representation of the state of a given economy in terms of investments in and revenues from Telecoms, as well as the quality of its full-time Telecom labor force. For example, given two hypothetical TEs with the values of 2 and 3 of the proxy *conversion efficiency*, one can immediately assess that one TE, ceteris paribus, can generate a higher levels of revenues from the same level of investments while using the same level of workforce, than another TE. Once the values of *conversion efficiency* were calculated for TEs in our sample, we then calculated the values of the variable *change in conversion efficiency*, representing the annual changes in the values of *conversion efficiency* for all of the economies in our sample. This allows us to construct two OLS models consisting of the variables listed in Tables 5 and 6.

Term in the first OLS model	Variable
Y1	TFP
X5	*Change in conversion efficiency (*annual change in ratios of *Total telecom services revenue (in current US $)* to *Annual telecom investment (in current US $),* per full-time Telecom worker.

Table 5 Variables in the first OLS model

The first OLS model allows for determining the presence of statistically significant relationships between the values of TFP, and the values of *change in conversion efficiency,* and utilizes the formulation of the following OLS model:

TFP = a + b_7 Change in conversion efficiency + e*

Term in the second OLS model	Variable
Y1	TFP
X5	*Conversion efficiency (*ratio of *Total telecom services revenue (in current US $)* to *Annual telecom investment (in current US $),* per full-time Telecom worker.

Table 6 Variables in the second OLS model

Using the second OLS model allows for determining the presence of statistically significant relationships between the values of TFP, and the values of *conversion efficiency,* and utilizes the formulation of the following OLS model:

$TFP = a + b_{8*}$ *conversion efficiency* $+ e$

Phase 4

DEA allows an investigator not only to obtain the scores of the relative efficiency for each DMU in the sample and to calculate MI to evaluate the overall growth in productivity, but also to decompose the values of MI into two components. The first component is represented by the change in technology (TC), and the second component is represented by the change in efficiency (EC) that took place during a period of time. Consequently, taking into consideration that TFP is represented by MI,

MI = TC + EC, we can express the possible contribution of investments in Telecoms to macroeconomic bottom line as a combination of two components:

First, *Investments in Telecoms - > Revenues from Telecoms -> GDP*, and

Second, *Investments in Telecoms - > (TC + EC) -> GDP*.

Resultantly, by knowing relative values of TC and EC we can determine whether the growth in productivity was primarily due to the technology (in the case of TC > EC), or due to the efficiency (in the case of EC > TC). This will allow us to gain insights into the nature of the weak link of the overall chain of the macroeconomic impact of the investments.

NULL HYPOTHESES OF THE STUDY

Phase 1

For the first phase of our inquiry we formulate the following two hypotheses. Given the value of MI, representing the annual change in TFP, and the value of AMI, representing averaged value of TFP from 1993 to 2002:

$H_1$0: For each of the 18 TEs in the sample for each year in the 1993-2002 period, MI <1

$H_2$0: For each of the 18 TEs in the sample for the period from 1993 to 2002, AMI <1

The similar hypotheses were formulated for the period from 2003 to 2008.

Testing of $H_1$0 allows us to identify TEs, which exhibited annual growth in TFP, while testing $H_2$0 allows us to identify TEs, which exhibited continuous growth in TFP over the given period.

Phase 2

Given the first MR model

$TFP = a + b_{1*}$*annual change in investments in Telecoms* $+ b_{2*}$*annual change in full-time Telecoms staff* $+ b_{3*}$ *annual change in investments in Telecoms*$_*$*annual change in full-time Telecoms staff* $+ e$

we formulate the following three hypotheses:

$H_3$0: $b_1 = 0$ *at* $\alpha = 0.05$ level

$H_4$0: $b_2 = 0$ *at* $\alpha = 0.05$ level

$H_5$0: $b_3 = 0$ *at* $\alpha = 0.05$ level

Testing $H_3$0 allows us to determine whether a given TE from 1993 to 2002, and from 2003 to 2008, exhibited a statistically significant relationship between changes in the level of investments in Telecoms and changes in TFP, while testing $H_4$0 allows us to determine whether a given TE from 1993 to 2002, and from 2003 to 2008, exhibited a statistically significant relationship between changes in the level of full-time Telecom staff and changes in TFP. Finally, Testing $H_5$0 allows us to determine whether for a given TE the changes in the level of investments in Telecoms and changes in the level of full-time Telecom staff produce a complementary effect on changes in TFP.

Similarly, given the second MR model

$TFP = a + b_{4*}$ *Annual telecom investment* $+ b_{5*}$ *Full-time telecommunication staff* $+ b_{6*}$ *Annual telecom investment* $_*$ *Full-time telecommunication staff* $+ \xi$

we formulate the following three hypotheses:

$H_6$0: $b_4 = 0$ *at* $\alpha = 0.05$ level

$H_7$0: $b_5 = 0$ *at* $\alpha = 0.05$ level

$H_8$0: $b_6 = 0$ *at* $\alpha = 0.05$ level

Testing $H_6$0 allows us to determine whether a given TE from 1993 to 2002, and from 2003 to 2008, exhibited a statistically significant relationship between the level of investments in Telecoms and TFP, while testing $H_7$0 allows us to determine whether such relationship existed between the level of full-time Telecom staff and TFP. Finally, Testing $H_8$0 allows us to determine whether level of investments in Telecoms and the level of full-time Telecom staff are complementary in terms of their effect on TFP.

Phase 3

The first OLS model utilizes the following formulation

$$TFP = a + b_{7*}\ Change\ in\ conversion\ efficiency + \xi,$$

and is concerned with the testing of the following null hypothesis:

$H_9$0: $b_7 = 0$ *at* $\alpha = 0.05$ level.

Testing $H_9$0 allows us to determine whether for a given TE changes in *conversion efficiency* impact TFP. The second model takes the form of

$$TFP = a + b_{8*}\ conversion\ efficiency + \xi,$$

and is concerned with the testing of the following null hypothesis:

H_{10}0: $b_8 = 0$ *at* $\alpha = 0.05$ level.

Testing H_{10}0 allows us to determine whether for a given TE *conversion efficiency* has an impact on TFP.

Phase 4

The last phase of our investigation relies on the following equation:

MI = TC + EC,

And is concerned with testing the following hull hypothesis:

H_{11}0: TC > EC.

Testing H_{11}0 allows us to determine whether the growth in productivity was primarily driven by a better technology, or whether it was driven by the improvements in efficiency.

RESULTS OF THE DATA ANALYSIS

To perform the DEA part of the data analysis we used the software application "OnFront," version 2.02, produced by Lund Corporation (www.emq.com), and we used *SAS Enterprise Miner* (EM) to conduct MR and OLS. The data subjected to MR and OLS were standardized prior to analysis. Table 6 contains the summary of the analysis.

Phase 1

We summarized the results of the first phase in the table below.

	Has the TE exhibited Annual Growth in Productivity? (Y/N)		**Has the TE exhibited Continuous Growth in Productivity? (Y/N)**	
Country	**1993-2002**	**2003-2008**	**1993-2002**	**2003-2008**
Albania	N	N	Y	N
Armenia	N	N	Y	Y

Azerbaijan	N	N	Y	Y
Belarus	N	N	Y	Y
Bulgaria	N	N	Y	N
Czech Republic	N	Y	Y	Y
Estonia	N	N	Y	Y
Hungary	Y	N	Y	Y
Kazakhstan	N	N	Y	N
Latvia	N	N	Y	Y
Lithuania	N	N	Y	Y
Moldova	N	N	Y	Y
Poland	N	N	Y	N
Romania	N	N	Y	Y
Slovak Republic	N	N	Y	N
Slovenia	N	N	Y	Y
Ukraine	N	N	Y	Y
YES: Proportion	0.06	0.06	1.00	0.71
Similarity between Periods	0.88		0.71	

Table 7 Results of the Phase 1, RQ 1 and RQ 2("Y"- the null hypothesis rejected, "N"- the null hypothesis accepted)

Phase 2

The results of the second phase of the data analysis are summarized in Table 8 and Table 9.

	First MR' model					
	Is there a Relationship between changes in the Level of Investments in Telecoms and changes in Productivity?		**Is there a relationship between changes in the Level of Full-time Telecom Staff and changes in Productivity**		**Does changes in the Level of Investments in Telecoms & changes in the Level of Full-time Telecom Staff produce a complementary effect on changes in Productivity?**	
Country	**1993-2002**	**2003-2008**	**1993-2002**	**2003-2008**	**1993-2002**	**2003-2008**
Albania	N	N	N	N	N	N
Armenia	N	N	N	N	N	N
Azerbaijan	N	N	N	N	N	N
Belarus	Y	N	Y	N	Y	N
Bulgaria	N	N	N	N	N	N
Czech Republic	N	N	N	N	N	N
Estonia	N	N	N	N	N	N
Hungary	N	N	N	N	N	N
Kazakhstan	N	N	N	Y	N	N
Latvia	N	N	N	N	N	N

Lithuania	N	Y	N	Y	N	N
Moldova	N	Y	N	Y	N	N
Poland	N	N	N	N	N	N
Romania	N	N	Y	N	N	N
Slovak Republic	N	N	N	N	N	N
Slovenia	N	N	N	N	N	N
Ukraine	N	N	N	N	N	N
YES: Proportion	0.06	0.12	0.12	0.18	0.06	0.00
Similarity between Periods	0.82		0.71		0.94	

Table 8 Results of the Phase 2, RQ 3, RQ 4, and RQ 5("Y"- the null hypothesis rejected, "N"- the null hypothesis accepted)

The insights offered by the result of the first MR model of the Phase 2 suggest that the level of investments in Telecoms and the level of the full-time Telecom workforce are not viable predictors of productivity growth. This simply means that no TE in our sample, other than Belarus, can claim that the level of investment in Telecoms serves as a determinant of the growth in productivity. It would appear that 17 TEs in our sample have already achieved a threshold level of investments sufficient enough to produce a stream of revenue, but insufficient by itself, and in absence of complementary investments, to produce any significant changes in productivity. Also, no TE, other than Belarus or Romania, can demonstrate that the growth in productivity is determined by the level of the full-time Telecom labor. This might mean that the rest of 16 TEs must concentrate not on increasing the quantity of full-time workers, but on increasing the quality of the existing level of their full-time workforce.

	Second MR' model					
	Is there a relationship between the Level of Investments in Telecoms & TFP?		**Is there a relationship between the Level of Full-time Telecom Staff & TFP?**		**Are the level of Investments in Telecoms & the Level of Full-time Telecom Staff complementary in terms of their effect on TFP?**	
Country	**1993-2002**	**2003-2008**	**1993-2002**	**2003-2008**	**1993-2002**	**2003-2008**
Albania	N	N	N	N	N	N
Armenia	N	N	N	N	N	N
Azerbaijan	N	N	N	N	N	N
Belarus	N	N	N	N	N	N
Bulgaria	N	N	N	N	N	N
Czech Republic	N	N	N	N	N	N
Estonia	Y	Y	Y	Y	Y	Y
Hungary	N	N	N	N	N	N
Kazakhstan	Y	Y	Y	Y	Y	Y
Latvia	Y	Y	N	N	N	N
Lithuania	N	N	N	N	N	N
Moldova	N	N	N	N	N	N
Poland	N	N	N	N	N	N
Romania	N	N	N	N	N	N
Slovak Republic	N	N	N	N	N	N

Slovenia	N	N	N	N	N	N
Ukraine	N	N	N	N	N	N
YES: Proportion	0.18	0.18	0.12	0.12	0.12	0.12
Similarity between Periods	1.00		1.00		1.00	

Table 9 Results of the Phase 2, RQ 6, RQ 7, and RQ 8 ("Y"- the null hypothesis rejected, "N"- the null hypothesis accepted)

Results of the second MR of the Phase 2 identified only Lithuania as an economy with a statistically significant impact of the level of investments in Telecoms and the level of full-time Telecom staff on changes in productivity (H_60 and H_70 were rejected). Results also suggest a presence of the complementary effect of the levels of labor and capital on productivity (H_80 was rejected). The other 17 TEs exhibited no relationship between the levels of capital investment and full-time labor, and productivity (H_60, H_70, and H_80 were accepted).

Phase 3

The results of the Phase 3 provided in Table 10.

	OLS models			
	Do changes in the Ratio of Revenues to Investments impact TFP?		**Does the Level of the Ratio of Revenues to Investments have an impact on TFP?**	
Country	**1993-2002**	**2003-2008**	**1993-2002**	**2003-2008**
Albania	Y	N	N	N
Armenia	N	N	N	N
Azerbaijan	Y	N	N	Y
Belarus	N	Y	N	N
Bulgaria	N	N	N	N
Czech Republic	N	N	N	N
Estonia	N	N	N	N
Hungary	N	Y	N	N
Kazakhstan	N	Y	N	N
Latvia	N	N	N	N
Lithuania	N	Y	N	N
Moldova	N	Y	N	Y
Poland	Y	N	N	N
Romania	Y	Y	N	N
Slovak Republic	Y	Y	N	N
Slovenia	Y	N	N	N
Ukraine	Y	N	N	N
YES: Proportion	0.41	0.41	0.00	0.12
Similarity between Periods	0.44		0.88	

Table 10 Results of the Phase 3, RQ 9 and RQ 10 ("Y"- the null hypothesis rejected, "N"- the null hypothesis accepted)

Phase 4

Summary of the results of the Phase 4 is provided in Table 11.

	DEA, Decomposition of MI	
	Do Changes in Technology serve as a primary engine of growth of TFP?	
Country	**1993-2002**	**2003-2008**
Albania	Y	N
Armenia	Y	N
Azerbaijan	Y	N
Belarus	Y	N
Bulgaria	Y	N
Czech Republic	Y	N
Estonia	Y	N
Hungary	Y	Y
Kazakhstan	Y	Y
Latvia	Y	Y
Lithuania	Y	N
Moldova	N	N
Poland	Y	N
Romania	Y	N
Slovak Republic	Y	N
Slovenia	Y	Y
Ukraine	Y	N
YES: Proportion	0.41	0.41
Similarity between Periods	0.44	

Table 11 Results of the Phase 4, RQ 11 ("Y"- the null hypothesis rejected, "N"- the null hypothesis accepted)

DISCUSSION OF THE RESULTS

We begin our discussion of the results of the investigation by evaluating the similarities that exist between the two periods. This will allow us to identify whether any significant changes took place between the period of the early transition and the period of the later transition. The assessment of similarities is provided in Table 12.

Issue	**Similarity between the Periods**
Has the TE exhibited Annual Growth in Productivity?	0.88
Has the TE exhibited Continuous Growth in Productivity?	0.71
Is there a Relationship between changes in the Level of Investments in Telecoms and changes in Productivity?	0.82
Is there a relationship between changes in the Level of Full-time Telecom Staff and changes in Productivity	0.71

Does changes in the Level of Investments in Telecoms & changes in the Level of Full-time Telecom Staff produce a complementary effect on changes in Productivity?	0.94
Is there relationship between the Level of Investments in Telecoms and TFP?	1.00
Is there a relationship between the Level of Full-time Telecom Staff and TFP?	1.00
Are the level of Investments in Telecoms & the Level of Full-time Telecom Staff complementary in terms of their effect on TFP?	1.00
Does changes in the Ratio of Revenues to Investments impact TFP?	0.88
Does the Level of the Ratio of Revenues to Investments have an impact on TFP?	0.44
What is the dominant source of improvement in Productivity? TC or EC?	0.29

Table 12 Assessment of the similarities between the two periods, 1993-2002 and 2003-2008

The assessment allows us to conclude that in regard to the first nine research questions no significant changes took place over time. For example, the results of the Phase 1 demonstrate that during the both periods most of the TEs in our sample exhibited growth in productivity.

The insights offered by the result of the first MR model of the Phase 2 suggest that the level of investments in Telecoms and the level of the full-time Telecom workforce are not viable predictors of productivity growth. Furthermore, the results of the second MR model of the Phase 2 indicate that the most of TE cannot demonstrate a presence of the link between the changes in the levels of investments and full-time labor, and changes in productivity. The results of the Phase 2 suggest that the TEs of the sample have already obtained the sufficient levels of Telecom-related capital and labor, and now they should concentrate on the efficiency and effectiveness of the utilization of investments and the quality of the full-time Telecom labor.

Moreover, the results of OLS of the Phase 3 allow us to conclude that in the context of our set of TEs a higher ratio of revenues to investments per full-time Telecom worker does not indicate a growth in productivity and the presence of spillover effect.

However, we can observe some dissimilarity between the two periods in regard to the RQ 10 and RQ 11. For example, or some of the TEs the changes in the ratio may reliably serve as a predictor of changes in productivity, which means that the growth in productivity is determined by the ability of these economies to do "more with less." Based on the results of OLS it is reasonable to conclude, then, that at least for some of the TEs economic growth associated with investments in Telecoms is determined by the presence of the skilled full-time Telecom workforce capable of efficiently and effectively converting investments into revenues.

Finally, the results of the Phase 4 demonstrate a major difference between the two periods in regard to the sources of the growth in productivity; while during the period from 1993 to 2002 most of the TEs in our sample exhibited growth in productivity fueled by technological changes (i.e., TC), in the 2003-2008 period growth in productivity was based on improvements in Efficiency (i.e. EC). This is more desirable since growth is associated with more efficient of utilization of the already available technology.

CONCLUSION

The results of our investigation raise questions that could serve as possible directions for future inquiries. First, what are some of the complementary factors that will allow investments in Telecoms to impact productivity growth? Second, what are some of the ways of improving the efficiency of conversion of investments in Telecoms into revenues? Third, what is the optimal revenue-to-investment ratio per Telecom worker that will indicate the need for the expansion of the full-time workforce?

One of the limitations of our inquiry is associated with the availability of the data; it has been noted that in the context of emerging market economies "researchers face sampling and data collection problems" (Hoskisson *et al.* , 2000). Thus, this limitation seems to be fairly common for such context, and we hope that contributions of this study outweigh its shortcomings.

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